AFFTC-PA-12495

An Integrated and Collaborative RF Test Infrastructure Presentation

Edward E. Sabat

AIR FORCE FLIGHT TEST CENTER
EDWARDS AFB, CA

26 July 2012

AFFTC

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
26-07-2012	Presentation/Briefing	July 2012 -

4. TITLE AND SUBTITLE

An Integrated and Collaborative Radio Frequency (RF) Test Infrastructure

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)

Edward E. Sabat

5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)

412TW/EWG/EWOI
30 Hoglan Avenue
BLDG 1030
Edwards AFB, CA 93524

8. PERFORMING ORGANIZATION REPORT NUMBER

AFFTC-PA-12494

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSOR/MONITOR'S ACRONYM(S)
N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release A: distribution is unlimited.

13. SUPPLEMENTARY NOTES
CA: Air Force Flight Test Center Edwards AFB CA CC: 012100

14. ABSTRACT

The Benefield Anechoic Facility (BAF) has partnered with various agencies to bring new T&E capabilities forward to ensure we deliver well-tested effective systems to the Warfighter. The DoD, industry and other interested agencies can collaborate and utilize this infrastructure. We have partnered and supported the Army, Navy, Air Force, NASA, partner nations, and other agencies. As part of a Major Range Test Facility Base (MRTFB), the BAF is readily available to the developer and T&E communities. It provides a broad spectrum of RF testing capabilities that include traditional or installed antenna testing, electronic warfare/information operations (EW/IO) system stimulation and response measurement, radar systems test and high intensity radiation field (HIRF) testing among others. But most importantly is the collaborative test capability for the interoperability and compatibility issues of today's Electromagnetic Environment (EME).

15. SUBJECT TERMS
RF Test Capabilities in an RF Anechoic Chamber for EW, IO, RWR, ECM, SIGINT, ELINT, COMINT, Antenna, Interoperability, Compatibility, Systems Testing

16. SECURITY CLASSIFICATION OF: **Unclassified**			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			412 TENG/EN (Tech Pubs)
Unclassified	Unclassified	Unclassified	None	30	**19b. TELEPHONE NUMBER** *(include area code)* 661-277-8615

Air Force Flight Test Center

War-Winning Capabilities … On Time, On Cost

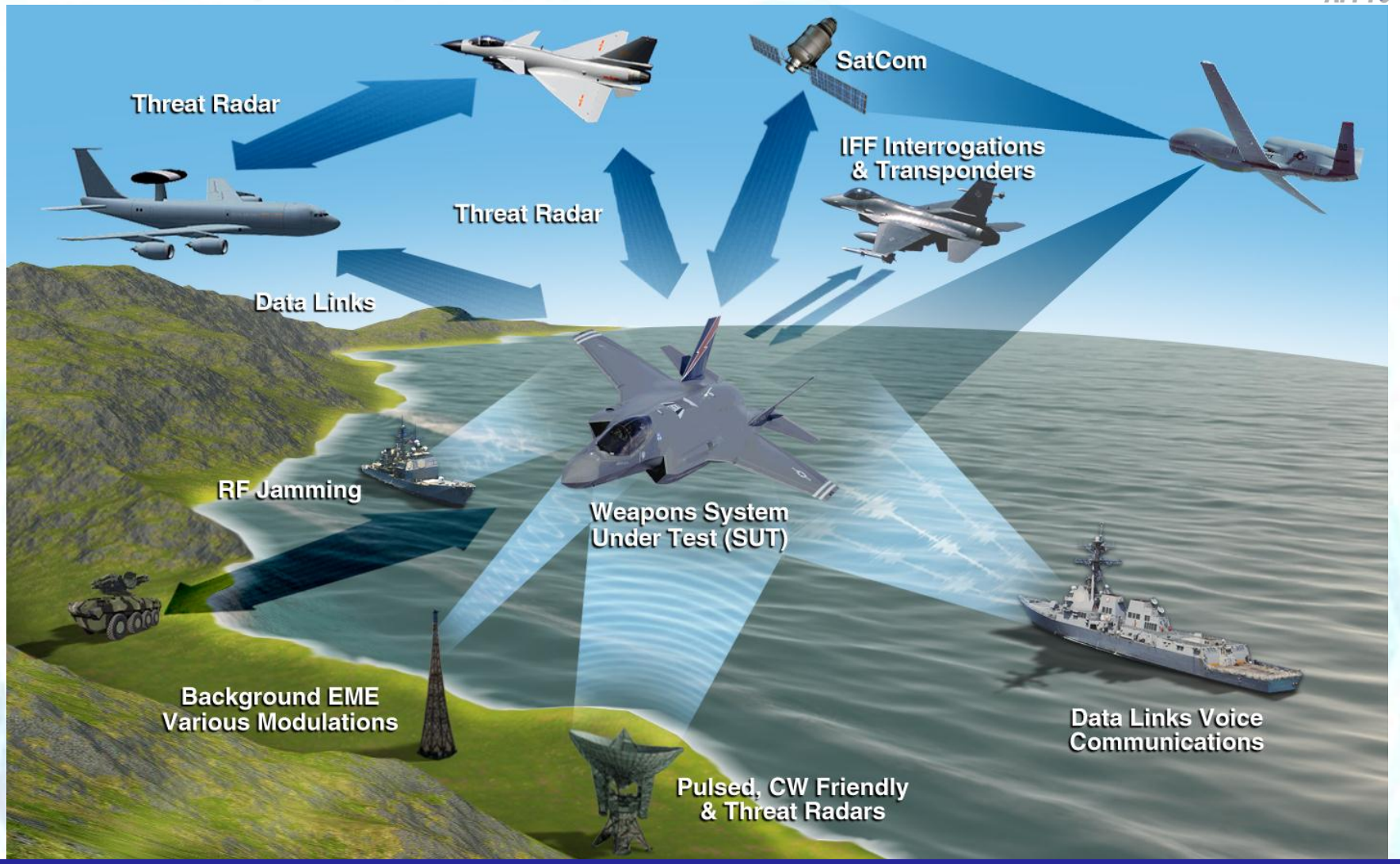
An Integrated and Collaborative RF Test Infrastructure

26 July 2012

412TW EWG 772d Test Squadron
Benefield Anechoic Facility (BAF)
Edward Sabat
661-277-8607
412TW.EWG.BAF@edwards.af.mil

The Challenge
EW/IO Systems Test in Today's EME

AFFTC



"Real world" RF Spectrum is a challenging one with extreme complexity

ISTF T & E Challenge

The installed systems test facility (ISTF) must support T&E requirements of <u>diverse</u> RF systems in this EME

- Electronic Warfare (EW) / Information Operations (I/O)
  - Radar Warning Receivers
  - Electronic Support
  - SIGINT/ELINT/COMINT
  - Electronic Attack (EA) (Jammers)
  - On-board and Off-board
- Radar systems
- Antenna systems for all types of avionics and RF systems
- IFFs, Data Links and Satellite Communications

<u>Manned and *Unmanned* Systems!</u>

Nearly "Anything RF" must be supported

Today's ISTF T&E Requirements

EW/IO Test Requirements that must be satisfied at the installed systems level:

- Present to the system or system-of-system (SoS) a near-real world environment – end-to-end-test capability at the mission level and free-space
  - Situational awareness – in the midst of a dense friendly and hostile threat EME
  - System performance (suitability, mission effectiveness, etc…)
  - Threat detection, parametric measurements, identification, processing, response
  - Direction finding (DF), installed antenna patterns and performance
  - Sub-system interoperability/compatibility testing: intra- and intersystem isolation
- ***And now, next generation weapons systems will be more complex and trickier to test…***

Must Mitigate surprises at the OAR or operationally

Future T&E Requirements

Next generation weapons systems will use multiple sensor inputs to detect, correlate, identify, geo-locate and respond to threats

- Complexity, Interoperability, multi-mission, etc…
  - Sensor fusion - SoS with multiple sensor working in concert to provide one solution
  - Networked systems – External data or sensor fusion
  - Smarter and more discriminating intelligent avionics
- New ISTF RF test paradigm with new techniques is needed, for example:
  - Simultaneously and synchronously stimulate multiple (possibly multi-spectral) sensors with higher density free-space than available at the limited ranges
  - More accurate and higher resolution measurements to meet system performance/demands
  - Systems with sophisticated sensor fusion will demand more sophisticated vehicle and avionics systems stimulation and simulation techniques
- All the above tested at the installed system level – ***The T&E Challenge***

Integration of new ISTF test capabilities needed

Capabilities Needed for Today's System

RF T&E infrastructure:

- An ***extraordinarily large anechoic chamber*** facility
- Complete ***RF end-to-end installed systems test***
- Dense, high fidelity ***RF threat simulations*** and verification
- Interactive ***data links and communications***
- ***Electronic countermeasures*** collection, measurement and analysis
- ***Radar target return*** and ***ECM simulation***
- ***Antenna pattern*** measurement
- Inter- and Intra-Systems Electromagnetic (EM) ***Interoperability and Compatibility (EMI/EMC)***
- ***Electromagnetic environmental effects*** (E3) measurements
- ***Global positioning system*** (GPS) signal generation
- Limited sensor fusion

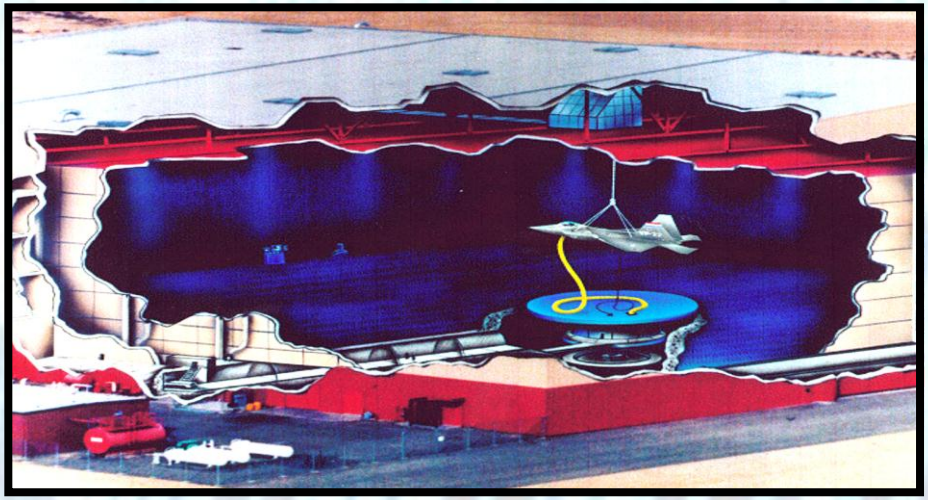
Provide the required environment and data for T & E

The BAF, an ISTF, for example, has brought together and nurtured a robust suite of free-space RF T&E capabilities to meet many of the T&E requirements of systems in a complex environment

- Brings the confidence level beyond that of the M&S and SIL

But…the growth of more complex RF-centric systems and systems-of-systems to respond to evolving and persistent threats is a challenge for ISTFs

The Current BAF Capability…



- **BAF Physical Layout (chamber)**
  - — 264 Ft L X 250 Ft W X 70 Ft H
- **Two 40-ton hoists**
- **175-ton 80-ft diameter turntable (One-of-a-kind capability)**
- **Power, Cooling (air and liquid), Hydraulics available**
- **Quiet Zone Isolation**
  - — 500 MHz* ≥ 72dB
  - — 1.0 GHz ≥ 84dB
  - — 2.0 GHz ≥ 96dB
  - — 3.0-18.0 GHz ≥ 100dB

  * Below 500 MHz special techniques are used to optimize with specific SUT
- **RF Shielding Effectiveness**
  - — To/from outside environment ≥ 100dB

"Virtual open-air range" within four walls

Dense and Complex EME Generation

Highly sophisticated – high fidelity and complex Electromagnetic Environment (EME) signal generation - radiated free-space to meet the customer's requirement

- Combat Electromagnetic Environment Simulator (CEESIM) – Threat and Friendly RF EW signals from .1 – 18 GHz
- Joint Communications Simulator (JCS) and others – Communication, Navigation and Identification (CNI) signals and command and control (C^2), and data links
- GPS simulation and re-radiation systems
- Cellular (GSM) RF communications
- Radar targets and ECM response
- Radiated Susceptibility High Intensity RF (HIRF) System

Create and see the EME picture before fielding system

Dense and Complex EME Generation

A variety of reprogrammable EME scenarios available from CEESIM, JCS and BAF CNI test assets:

- Realistic threat lay-downs can be planned, scripted and used to stress system designs and pre-fly the system in the BAF
- Correlated to open air ranges or “real world”
- Selectable antenna and scan patterns
- Full variety of modulations (e.g., AM, FM, PM, FSK, PSK)
- Can be complementary to available EME at test ranges
- Land-based, Sea-based, Airborne radars
  - Early warning, acquisition, tracker, launch simulations
  - CW, pulsed ranging, Doppler
- Special or unique assets

A preview to what is expected on range or operationally

Dense and Complex EME Generation

A variety of reprogrammable EME scenarios available from CEESIM, JCS and BAF CNI test assets:

- IFF Modes 1, 2, 3/A, 4, C, Mode S and Mode 5 Interrogators - AIMS Certified (late 2012)
- TACAN - Ground Beacon, Air Interrogators
- Voice Communication
- Voice Files, A/D Input
- Actual Radios
- Data Links - Coherent and scripted content (includes Link 16)
- Background Analog and Digital Signals
- AM, FM, SSB, PN Noise,…
- BPSK, QPSK, ASK, FSK, MSK, QAM,…
- Suitable for background noise and Jammers
- GPS – Simulators or Re-radiation into chamber

A preview to what is expected on range or operationally

CEESIM EME

CEESIM provides:

- **Land-based, Sea-based, Airborne radars**
- **Early warning, acquisition, tracker, launch simulations**
- **CW, pulsed ranging, Doppler**
- **Various high fidelity modulations**
- **Dynamic scenarios of these signals as scripted by the customer requirement**

Control Computer and GUI → **Digital Generation System** → **Mobile Distribution Patch Unit**

Modulations include AM, FM, PM, FSK, PSK, and others.

Low Band RF Generation Mobile Carts (4)

Low Band: 0.1 – 2 GHz 4 Channels

Mid Band RF Generation Mobile Carts (4)

Mid Band: 2 – 6 GHz 8 Channels

Dual Band RF Generation Mobile Carts (4)

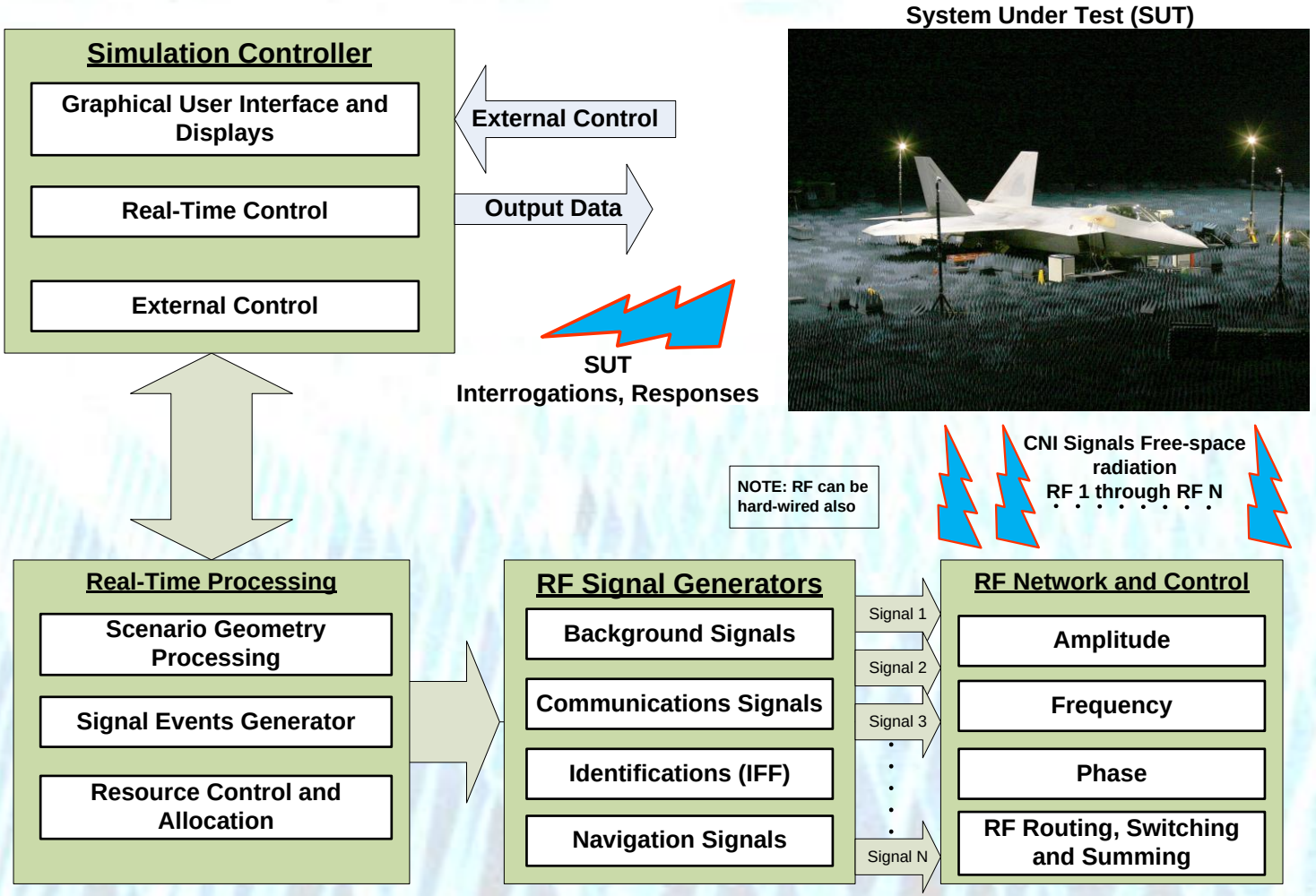
High Band: 6 – 18 GHz 12 Channels

High Band RF Generation Mobile Carts (8)

- **Antenna Height adjustable from 7 – 35 ft**
- **Aircraft Position: Up to approx. 50 ft depending on aircraft (or SUT on turntable)**
- **20 carts provide up to 24 highly mobile reconfigurable and reprogrammable channels as dedicated or multiplexed channels for higher density scenarios**

Free-Space CEESIM RF Scenario Generation

JCS EME



The JCS provides:

- Communications, Navigation and Identification (CNI) signals and command and control (C^2)

Complete Avionics Interoperability "Testability"

Radar Testing

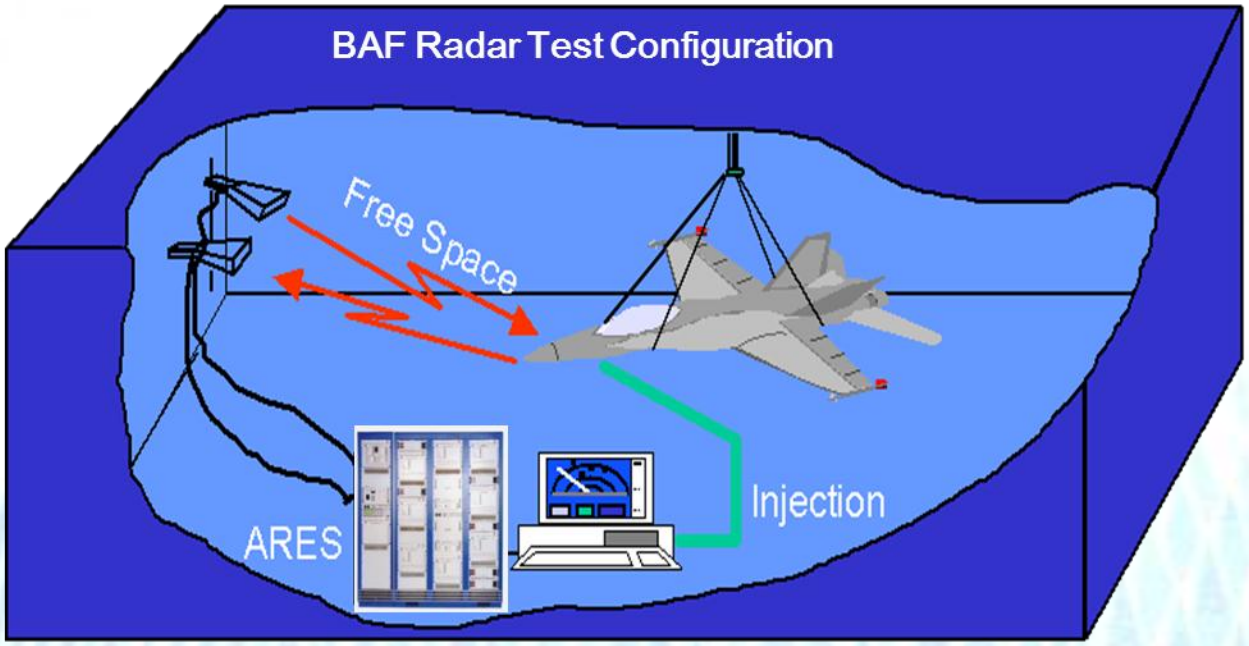
Provide radar systems test capabilities and radar target generation

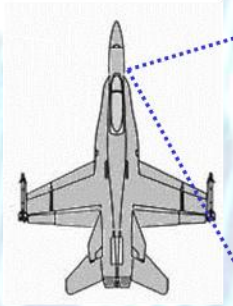
- Radar targets
  - DRFM based responses to SUT radar emissions
  - Provide range, range rate, and Doppler
- Coherent jammer responses
- Returns slaved to radar scanning
- Free space or direct injection
- ***New capabilities integrated***
  - ***Expanding the operating range from X-Band to a new much wider 300 MHz to 40 GHz operating range***
  - ***Radar data capture implemented***

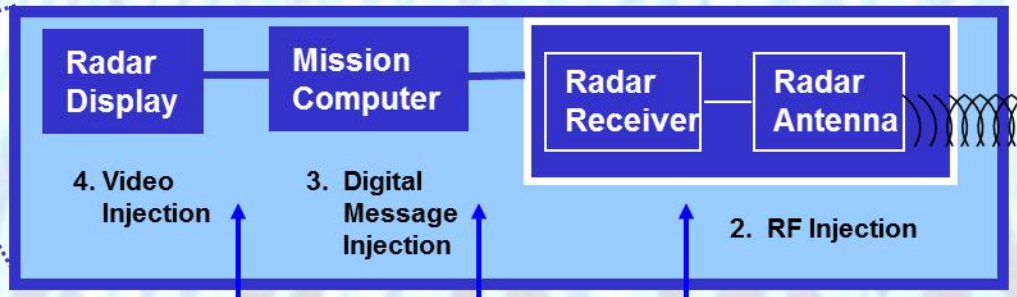
Complete Avionics Interoperability "Testability"

Radar Testing

Radar Test Scenario







Facility Interface

External ECM

1. RF Two-Way Free Space + IFF/RCS/JEM

Complete Avionics Interoperability "Testability"

GPS Simulation and Test

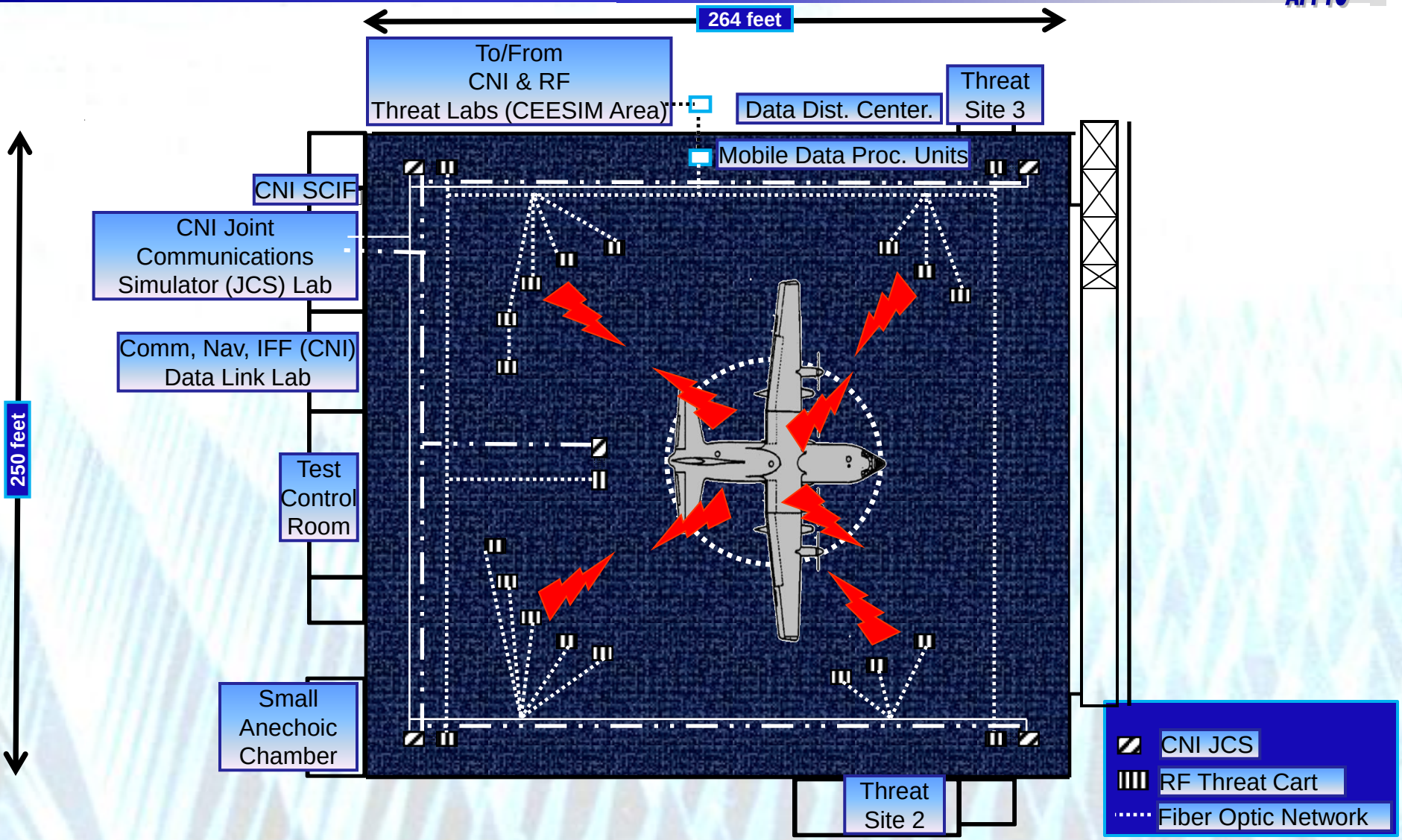
Global Positioning System (GPS) GPS integration, tracking and jamming tests must be supported

- Internally controlled , no regulatory agency approval required
- GPS Retransmission system
  - Repeats external real world signals - single point
- Interstate GPS Simulator
  - Twenty four (24) satellite signals (single point transmission)
- ***New Advanced Global Navigation Simulator (AGNS) (late 2012)***
  - ***Expands capabilities to meet newer test requirements***
  - *Sixteen RF channels into seven (7) separate L1 and L2 transmit antennas*
  - *Simulates C/A , L2C, P and P(Y) and M codes for Advanced Encryption Code (AEC)*
  - *Modernized NAVSTAR Security Algorithm (MNSA) capable*


GPS Simulation

GPS - Critical element for today's systems

Typical Test Setup



An Orchestration of a Suite of Complementary Equipment

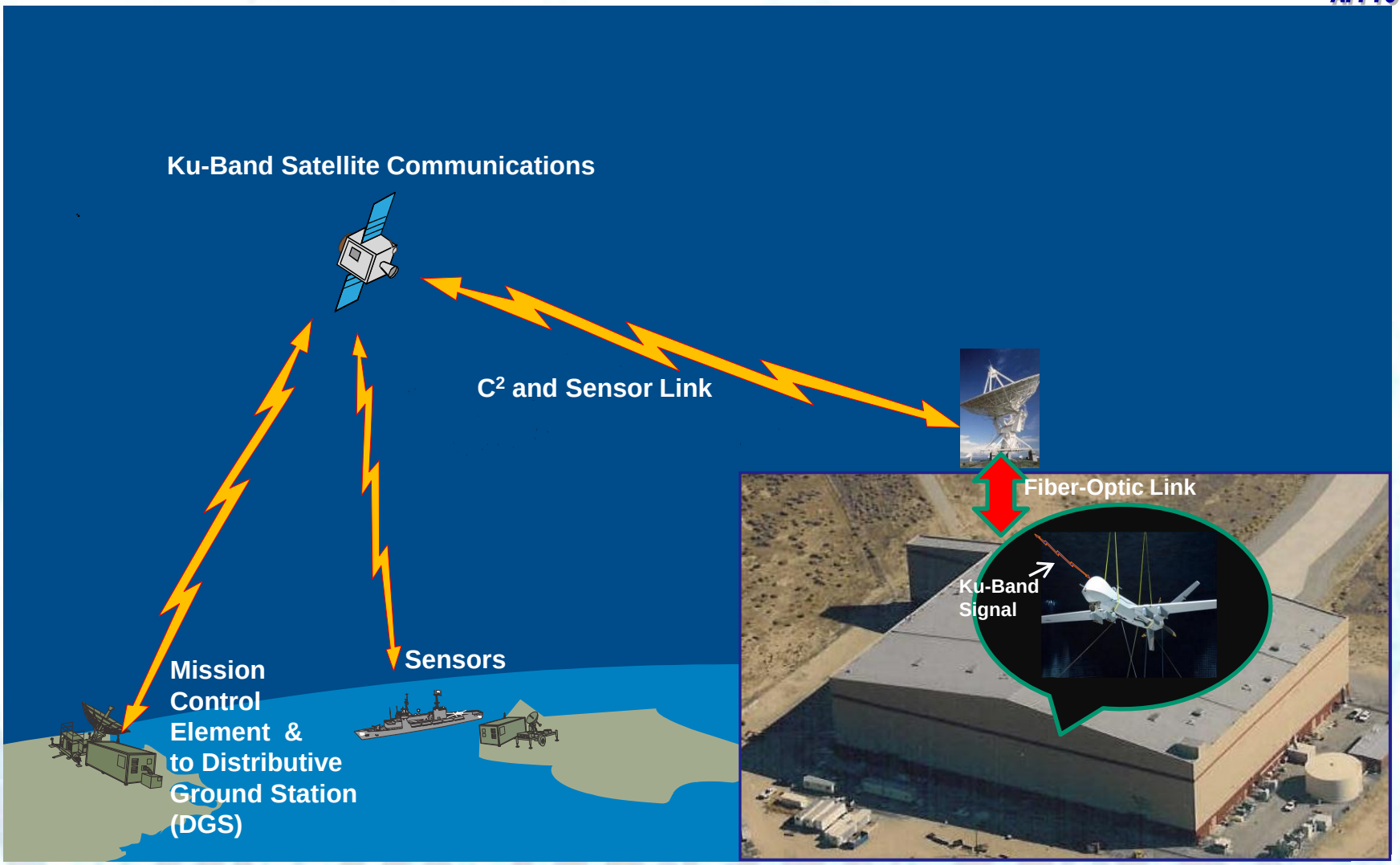
Distributive Testing and Connectivity

Testing interactively with an external facility or asset may be a significant requirement especially with UASs

- ***New Ku-Band SatCom (July 2012)***
  - ***New capability to meet UAV test requirements***
  - Uplink and downlink connectivity with Ku-Band SatCom-equipped SUT
  - Suitable for any Ku-Band SatCom-equipped aircraft - ***highly desirable for UASs***
- Connectivity with Other test facilities
  - Member facility of the Joint Mission Environment Test Capability (JMETC)
  - DIS, TENA, JREAP architectures
  - DREN, SDREN networks

Integrates remote assets, sensors and mission control elements

Ku-Band SatCom Link

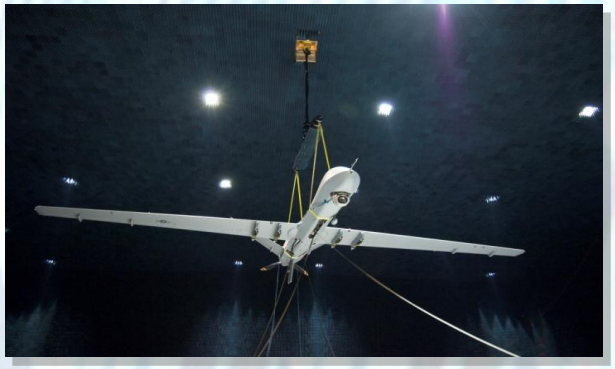


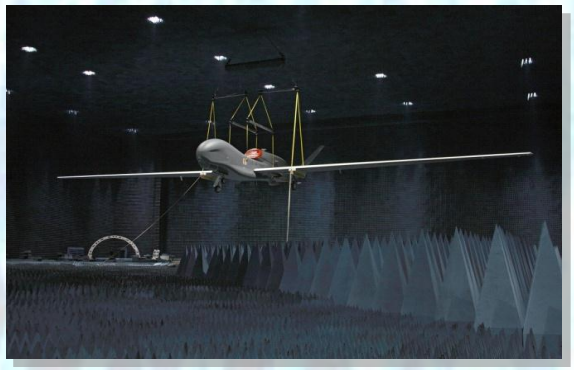
Integrates remote assets, sensors and mission control elements

Electromagnetic Environment Effects (E^3)

Today's highly integrated weapons systems must operate in challenging EMEs and meet demanding integration and interoperability requirements

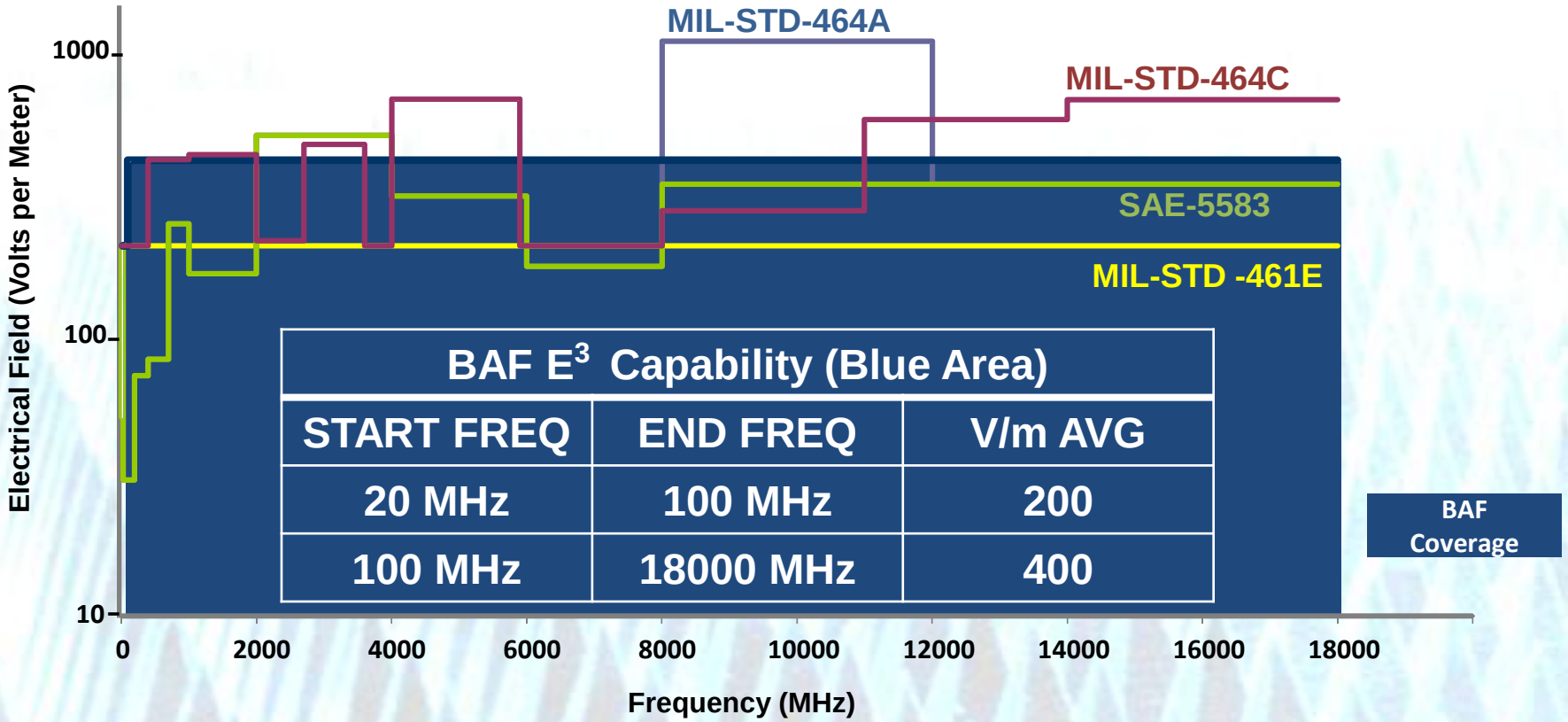
- ***New Enhanced E^3 capability – implementation for HIRF (Sept 2012)***
  - Radiated Emissions (IAW MIL-STD 461)
  - Radiated Susceptibility (IAW MIL-STD 464)
- Inter- and Intra-system Interoperability
  - Antenna isolation (Source-Victim)
  - Systems to systems effects (EMI/EMC)





Ensure suitability, mission effectiveness and safety of flight

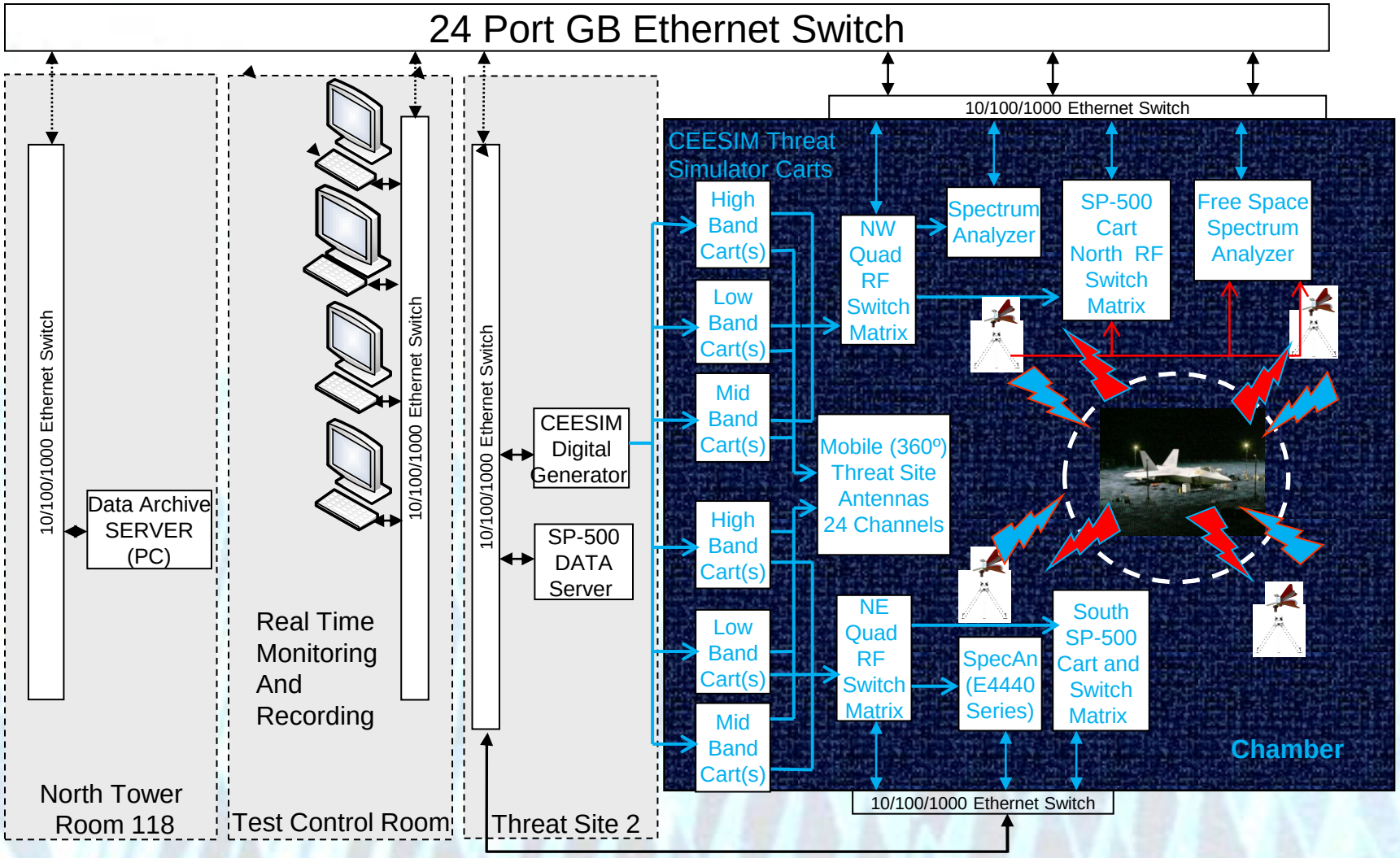
Electromagnetic Environment Effects (E^3)



BAF E^3 Capability (Blue Area)		
START FREQ	END FREQ	V/m AVG
20 MHz	100 MHz	200
100 MHz	18000 MHz	400

Comparison among Typical Standards

RF Monitoring Capabilities

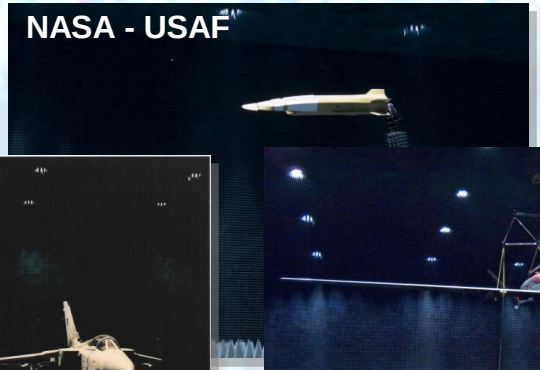


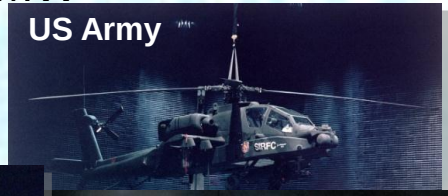
Sample of RF Monitoring Configuration for Chamber

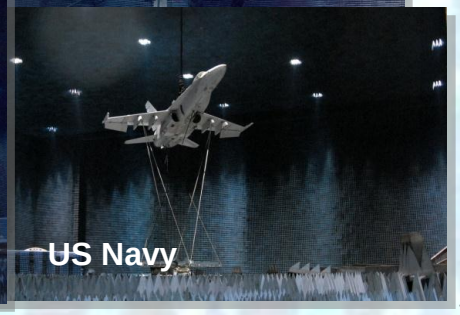
Snapshot of Prior Tests

A history of quite a diverse customer base and test requirements for such platforms as,

- USAF: F-22, CV-22, C-130, C-17, RQ-4, MQ-1/9, F-16, F-15, B-1B, B-52, U2
- US Navy: F/A-18 Hornet/Super Hornet, F-14, Harrier, Lear RCS
- US Army: Apache, MH-47 (Chinook)
- NASA: F-15, F-16, MISTI, X-43, X-51
- FMS: RAAF F/A-18, Israeli F-15, Pakistani F-16
- Foreign: UK Typhoon and Tornado, EuroHawk
- Commercial: Boeing RAAF Wedgetail, F-15 Singapore, BMW







Collaboration

Recognize the need for and existence of various test facilities with specific capabilities (Major Range Test Facility Bases (MRTFBs))

- Collaboration and support of the *right test at the right facility* in a cost-effective manner is imperative
- Must meet with potential customer
  - Understand and evaluate requirements - What facility is the best facility for the test?
  - Point customer to other test facilities if it is in the customer's best interest or...
  - Team with other facilities to best meet customer and technical needs
- The BAF actively participates in joint T&E activities and capability development
  - Presently need to address the multi-sensor fusion and density test capability
- MRTFBs should accommodate DoD, FMS and commercial customers



Summary

A highly capable and robust T&E ISTF infrastructure to support the DoD, industry and our allies in the test of today's highly integrated weapons systems for today's EME is essential

- Developmental Test (DT) and Operational Test (OT)
  - Installed systems integration verification and baseline
  - Realistic integrated, dense, controllable and secure test environment
  - Validated, correlated, and coordinated signals - correlation to open-air range assets
- Secure test environment for sensitive signals (SAP, SCI, War Modes) to support DT and OT Battle-Space environment or when restricted by regulatory agencies
- ISTF takes systems test confidence to levels above that of M&S or a SIL
- ***A need for the stimulation and control of the newer smarter systems is still needed for the next generation systems***
  - ***Collaboration among developers (government and industry) and testers needed to integrate test capabilities into key ISTF facilities***

Major T & E capabilities available, always adapting to systems

Contact Information

412TW EWG

772d Test Squadron

Benefield Anechoic Facility

30 Hoglan Ave

Edwards AFB, CA 93524

Ed Sabat

661-277-8607

412TW.EWG.BAF@edwards.af.mil

edward.sabat@edwards.af.mil

Fly it in an ISTF before you take it outside and play!

Antenna Pattern Measurements

Measurement resources must provide stand-alone and installed patterns of passive and active antennas

- Frequency range 0.1 to 18 GHz
  - Time gating techniques are applied for lower frequencies (≤ .5 GHz) or for other special requirements
- Rapid automated data collection
  - Multiple frequencies, angles, and polarizations can be collected within a single sweep
- High rate of data collection in an installed system environment
  - Useful for the population of system performance and mission planning models